Detecting Alerts, Notifying the Physician, and Offering Action Items: A Comprehensive Alerting System

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We developed and evaluated a system to automatically identify serious clinical conditions in inpatients. The system notifies the patient's covering physician via his pager that an alert is present and offers potential therapies for the patient's condition (action items) at the time he views the alert information. Over a 6 month period, physicians responded to 1214 (70.2%) of 1730 alerts for which they were paged; they responded to 1002 (82.5% of the 1214) in less than 15 minutes. They said they would take action in 71.5% of the alerts, and they placed an order directly from the alert display screen in 39.4%. Further study is needed to determine if this alerting system improves processes or outcomes of care.

INTRODUCTION

Studies indicate that the treatment of serious clinical conditions in inpatients is frequently delayed and that information technologies can help alleviate the problem. Bates[1] found that 4.1% of all adverse events might have been prevented by improved communication of panic laboratory results and another 5.5% by the detection of drug-laboratory interactions. Tate[2] found that the fraction of "life-threatening" laboratory results that were treated appropriately increased from 51% to 63% ($p<0.05$) if alerts about such situations were displayed when the patient's laboratory data were reviewed. Rind[3] found that the time to adjust nephrotoxic or renally excreted medications in the presence of a rising creatinine decreased from 97.5 to 75.9 hours ($p<0.001$) if electronic mail alerts were sent to physicians who were likely involved with the patient's care.

Despite these success stories, when automated laboratory alerting systems are planned, two questions continue to surface: "Who do you tell about an alert once it is detected?" and "How do you tell them?". These questions are vexing. Tate[2] displayed the alert information to anyone who reviewed the patient's laboratory data; Rind[3] sent an e-mail alert to anyone who had reviewed the patient's data in the preceding 3 days.

More recently, Tate[4] communicated alerts via an interface to a paging computer although the recipient of the alert has been the patient's nurse. Ideally, the information should be communicated directly to the patient's covering physician since he must make treatment decisions based on the data.[5] In most hospital information systems, however, the identity of the covering physician is not known.

Also, because serious clinical conditions are likely to require treatment of some kind or another, an ideal alerting system would allow the recipient of the alert to take action at the same time he receives the alerting information.

The goals of this project were to address these issues. Specifically, we set about to develop a system that would 1) detect serious clinical situations (alerts), 2) notify the responsible physician about the condition or, failing that, to inform a nurse on the patient's floor, and 3) facilitate the physician's treatment of the condition by presenting "action items" (i.e., potential orders for treatment of the condition) to the physician acknowledging the alert.

BACKGROUND

The work was done at Brigham and Women's Hospital (BWH), a 750-bed tertiary care academic medical center in Boston, Massachusetts. Medical and surgical inpatients at BWH are covered by housestaff physicians. Computing services at BWH are provided by the Brigham Integrated Computing System (BICS). BICS runs on a personal computer-based local area network; most application software is internally developed in Mumps and data are stored in a Mumps database. Relevant clinical applications in place at BWH at the time this project started included 1) a comprehensive results review application[6], 2) a patient-provider coverage list application[7], and 3) an inpatient physician order entry application[8].

SYSTEM DESIGN

The design of the automated alerting system is shown in Figure 1.

Alert detection: As new data enter BICS, (e.g., new laboratory results, new medication orders, etc.), a copy is sent to an inference engine. The inference engine examines a knowledge base to determine if any rules have become true as a result of the new data. The structure of the knowledge base has been described previously[9].

Notification: If the inference engine determines that one or more rules are true as a result of the new data, a notification module is called to generate a page to the covering physician via an interface to the hospital's paging computer. The coverage list database[7] is accessed to determine who is covering the alerting patient.

The physician is paged to "8888". Physicians know that this means that an automated alert has been generated on one of their patients and that they should sign on to a BICS workstation to view the alert. If the physician is unable to access a workstation but can get to a telephone, she can dial 8888 to be connected to the Telecommunications office and an operator there will view the alert and read it to her.

If, after 15 minutes the alert has not been viewed by a physician, the borders of the workstations on the patient's floor turn red. These workstations are known as "pod monitors" and their default display is the list of patients on the floor with flags indicating tasks to be performed (e.g., orders to be taken off, pending renewals, etc.). The red border indicates that an alert is present for one of the patients. The alerting patient's status line displays the word "Alert". Any nurse or secretary on the floor may view the alert.

If the alert has not been viewed for 30 more minutes, a workstation in Telecommunications (staffed 24 hours a day, 7 days a week) starts to beep and displays the patient's name, the alert message, and the phone number of the patient's floor. The phone operator calls the floor and reads them the message. The phone operators are the final step in the "alert notification failsafe sequence".

Several special cases of the notification procedure have been considered and managed: 1) if the alerting patient is in the operating room (OR) or recovery room (as determined by computerized logs), the alert is not communicated; 2) if, for the patient, the coverage list application returns no physician or a physician with an unknown pager number, or if the covering physician is recorded as being in the OR, the alert is displayed on the pod monitor; 3) if the paged physician is not the covering physician and she knows the correct physician, she may redirect the alert to the correct physician (this generates a second page). If they do not know the correct covering physician, they may so indicate and the alert is instead displayed on the pod monitor on the patient's floor.

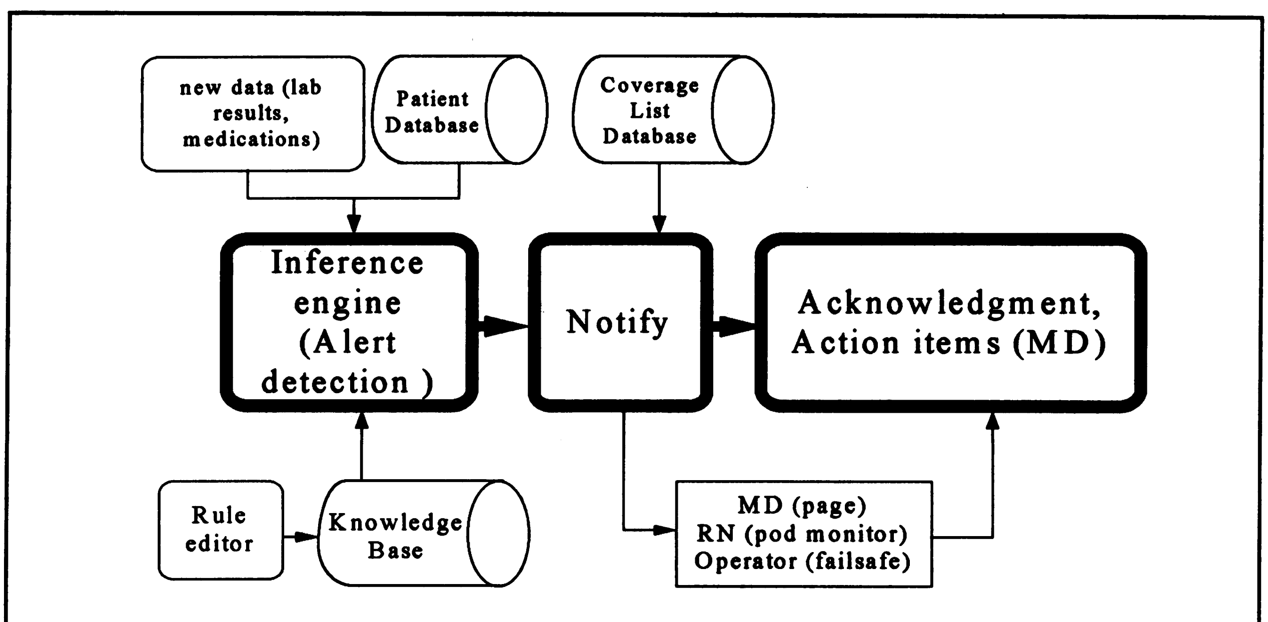

Figure 1. Alerting system architecture. See text for details.

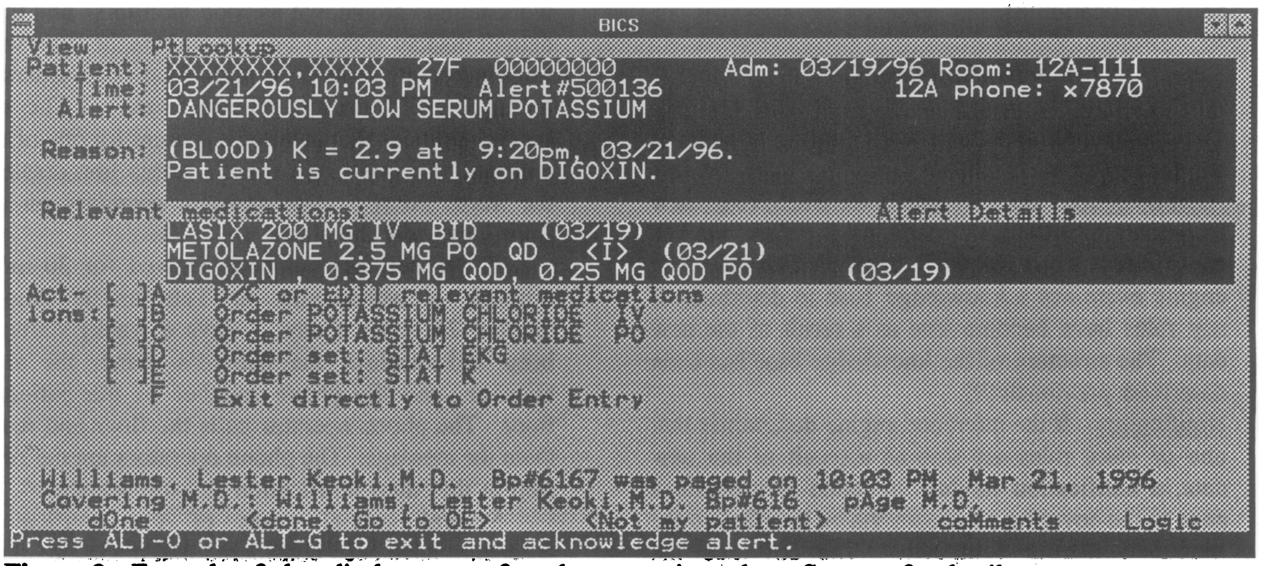

Figure 2. Example of alert display screen for a low potassium alert. See text for details.

Viewing the alert, action items, and acknowledgement: When a paged physician logs on to a BICS workstation, she is presented with an "alert display screen". Figure 2 shows an example of a hypokalemia alert display. Patient identifying information is shown at the top. The title of the alert is shown together with the data that caused the rule to evaluate true. Next, all relevant medications for this patient for this alert are displayed. Relevant medication, defined for each rule using the rule editor, are medications which are relevant to the alerting situation. In the example, the patient is receiving lasix, metolazone, and digoxin -- all relevant in the presence of serious hypokalemia.

Action items offered to the physician are displayed next. If there are relevant medications for this alert, the first action item is the opportunity to discontinue or edit any of the relevant medications. This is achieved through a link to the order entry program[8]. Other action items are also defined using the rule editor and include 1) entering new medication orders, and 2) entering non-medication orders (e.g., laboratory tests). In Figure 2, the action items for the low potassium alert include 1) order potassium IV, 2) order potassium PO, 3) order an EKG, and 4) order a repeat potassium level. The physician also has access to the patient's laboratory results (Patient Lookup on the menu bar).

After viewing the alert and taking actions, the physician enters "Done" to acknowledge the alert. The physician may also exit directly to order entry to write other orders not offered directly on the alert display screen. The physician is then presented with a single multiple choice question to determine her attitude towards the alert. An alert is also considered acknowledged when viewed by a nurse or communicated by a phone operator to the patient's floor. Action items are not offered to nonphysicians.

RESULTS

The automated alerting system became operational for the medical service in June, 1994 and for the surgical service in June, 1995. To evaluate the system's performance, we examined all alerts generated from 9/15/95 to 3/15/96 (6 months). This time period included 10,064 medical and surgical admissions at our hospital accounting for 63,000 patient-days.

Alerts: A total of 1945 alerts were generated by the system in 6 months. For 93 alerts (4.8%), no one was notified because the patient was in the operating room or recovery room. In these settings, the responsible care giver is difficult to identify and the patients are receiving a high level of attention in any case. The remaining 1852 alerts were generated by 20 rules. Their frequency of occurrence is shown in Table 1. The 4 most common alerting rules accounted for 79.5% of all alerts.

Notification and acknowledgement (Table 2): For 122 (6.6% of 1852) alerts, no physician or the wrong physician was paged; however for 18 the wrongly paged physician knew the correct physician and a second page went out in a timely manner. Physicians were signed into the OR 8 times.

For the 1730 times where the apparently correct covering physician was paged in a timely manner, the physician acknowledged the alert 1214 (70.2%)

Table 1. Number of alerts generated by each rule. Simple threshold logic is shown in parentheses. Other rules involve more complex logic.

Rule name	# occurrences/6 months
Hypokalemia	547
Hyperglycemia (serum glucose > 400)	490
Hyperkalemia (serum potassium > 6.0)	233
Falling hematocrit	202
Falling platelets and heparin	70
Potassium and high K	64
Hypoglycemia (serum glucose < 40)	43
Anticoagulants and low platelets	41
NSAIDS and low platelets	38
Renal failure and meperidine	35
Hyponatremia	28
K-sparing med and high K	16
Renal failure and propoxyphene	16
Hypernatremia (serum sodium > 155)	15
Renal failure and ethacrynic acid	5
Renal failure and reserpine	3
Demerol and MAOI	2
Renal failure and dextran	2
Serotonin agonists and MAOI	1
Renal failure and tetracyclines	1
	1852

Table 2. Six months of automated alerts.

1945 total alerts generated by system
  93 suppressed because patient in operating room or recovery room (4.8% of 1945)
1852 communicated alerts
  84 sent directly to pod monitor (4.5% of 1852)
    76 no MD/beeper found (4.1% of 1852)[1]
    8 MD in OR
  56 paged MD not covering (3.0% of 1852)[1]
    38 correct covering MD unknown, sent to pod monitor
    18 correct covering MD known, page regenerated
1730 pages sent out (1852-[84+38])
  1214 acknowledged by MD (70.2% of 1730)
    1002 acknowledged in <15' (82.5% of 1214)
    1199 ack'ed via workstation (98.8% of 1214)
      15 ack'ed by calling in (1.2% of 1214)
  506 sent to pod monitor (29.2% of 1730)
638 total annunciated on pod monitor (506+[84+38], 34.4% of 1852)
  316 acknowledged by nurses (49.5% of 638)
  322 acknowledged by operators (50.5% of 638)

[1] coverage list incomplete/incorrect

times, 1002 (82.5% of 1214) within 15 minutes. Physicians acknowledged 1199 alerts at a workstation and 15 by telephone. Physicians said they would take action as a result of the alert 857 times (71.5% of 1199, Table 3).

Of the 638 alerts displayed on the pod monitor, nurses acknowledged 316 (49.5%) and 322 (50.5% 18.3% of all 1852 communicated alerts) were acknowledged by the phone operators.

Action items (Table 4): Of the 1199 alerts acknowledged by physicians at a work station 99% presented at least one order as an action item. Physicians chose at least one order in 286 (23.9%). In 205 (17.1%) alerts, physicians exited to order entry after reading the alert, probably to enter an order not offered as an action item.

LESSONS LEARNED

The major distinctions between this project and previous efforts at alerting systems are that we tried to notify the patient's covering physician directly and we attempted to offer useful therapies (action items) at the time the alert was reviewed.

Physicians responded to pages 70.2% of the time. We do not know why physicians did not respond the rest of the time. It is possible they were busy with patients or education (or in the OR but not signed in as such) and could not get to a phone or workstation. It is possible that the coverage list was incorrect and the wrong physician (not in the hospital) was paged. We documented that coverage list was incorrect at least 6.6% of the time but this figure might have been higher. Also, some of our rules overlapped with the laboratory's panic values. Occasionally a viewed alert would contain the same information as that received from the lab (via the unit secretary). This might lower the urgency to respond to subsequent alert pages. Another potential explanation for the incomplete response rate is that some physicians may have felt that the alert pages were not important enough to pursue. Likely, some combination of all of the above was responsible. We are generally pleased that physicians receive our

Table 3. MD responses to post-alert questionnaire

Physician answer	% of 1199
Will take action as a result	857 (71.5%)
Was already aware of this condition	213 (17.8%)
Alert is interesting, no action needed	47 (3.9%)
Data are incorrect, false positive	30 (2.5%)
Alert is not interesting	19 (1.6%)
Other (freetext)	56 (4.7%)

Table 4. Summary of action items.

Action item	# times offered (% of 1199)	# times ordered (% of 1199)
New medication	836 (69.7%)	152 (12.7%)
Non-med order	1006 (83.9%)	111 (9.3%)
Relevant med	730 (60.9%)	47 (3.9%)
Any of above 3	1187 (99.0%)	286 (23.9%)
Exit via OE	all	205 (17.1%)
Any of above 2	all	472 (39.4%)

alerts directly 70.2% of the time. We are also pleased that physicians said they would take action in 71.5% of the alerts. This is an indication that they find the information useful. The fact that they placed an order *immediately* in 39.4% is also a measure of the seriousness of the communicated information.

We were surprised that the response rate of the nurses to alerts displayed on the pod monitor was only 49.5%. We assumed that they would be sufficiently interested in new information to view most alerts in a timely manner. Here, too, a combination of factors was likely at play. As with the physicians, the redundancy of some alerts with previously communicated information from the lab might have diminished the sense of urgency. Educating the nurses about the system was difficult. Various approaches were tried however many nurses may not have realized the importance of the alerts. The fact that the alerts were uncommon was problematic because a long time might pass between the inservice and an alert.

We tried to offer the physicians useful action items. In 23.9% of the alerts viewed on a workstation, they chose one of the action items we offered them. However because they exited to order entry in 17.1% of the alerts, it is likely that additional action items on the display screen could have been useful.

Finally, this study has examined the frequency with which physicians respond to pages about alerts on their patients. Our current work is focusing on whether this intervention impacts important medical process parameters, such as the time until medical therapy is started. Ideally, future work will determine the impact of such systems on medical outcomes such as the frequency of adverse events and length of stay.

CONCLUSIONS

When alerts about their patients were communicated via page to physicians, the physicians responded 70.2% of the time. When they responded at a hospital workstation, they said they would take an action as a result of the message 71.5% of the time and they placed an order at the time they viewed the alert 39.4% of the time. Nurses responded to alerts displayed on pod monitor workstations 49.5% of the time. Further work will involve determining if this system impacts processes and outcomes of care.

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REFERENCES

1. Bates DW, O'Neil AC, Boyle D, et al. Potential identifiability and preventability of adverse events using information systems. J Am Med Informatics Assn 1994;1:404-411.

2. Tate KE, Gardner RM, Weaver LK. A computerized laboratory alerting system. MD Comput 1990;5(7):296-301.

3. Rind DM, Safran C, Phillips RS, et al. Effect of computer-based alerts on the treatment and outcomes of hospitalized patients. Arch Intern Med 1994;154:1511-1517.

4. Tate KE, Gardner RM, Scherting K. Nurses, pagers, and patient specific criteria: three keys to improved critical value reporting. Symposium for Computer Applications in Medical Care (SCAMC) 1995;19:164-168.

5. Lundberg GD. Critical (panic) value notification: an established laboratory practice parameter. Editorial. JAMA 1990;263:709.

6. Safran C, Slack WV, Bleich HL. Role of computing in patient care in two hospitals. MD Comput 1989;6(3):141-148.

7. Hiltz FL, Teich JM. Coverage list: a provider-patient database supporting advanced hospital information services. Symposium for Computer Applications in Medical Care (SCAMC) 1994;17:809-813.

8. Teich JM, Spurr CD, Flammini SJ, et al. Response to a trial of physician-based inpatient order entry. Symposium for Computer Applications in Medical Care (SCAMC) 1993;17:316-320.

9. Kuperman GJ, Teich JM, Bates DW, et al. Representing hospital events as complex conditionals. Symposium for Computer Applications in Medical Care (SCAMC) 1995;19:137-141.